COORDINATED CHEMICAL AND ISOTOPIC STUDIES OF GEMS GRAINS IN IDPS. L. P. Keller and S. Messenger. ARES, Mail Code KR, NASA Johnson Space Center, Houston, TX 77058 (Lindsay.P.Keller@jsc.nasa.gov).

Introduction. Cometary IDPs contain a record of the building blocks of the solar system including presolar grains, molecular cloud material, and materials formed in the early solar nebula [1]. Following their accretion, these materials have remained relatively unaltered because of the lack of parent body hydrothermal alteration. We are using coordinated transmission electron microscope (TEM) and ion microprobe studies to establish the origins of the various components within cometary IDPs. Of particular interest is the nature and abundance of presolar silicates in these IDPs because astronomical observations suggest that crystalline and amorphous silicates are the dominant grain types produced in young main sequence stars and evolved O-rich stars [e.g. 2]. Amorphous silicates (in the form of GEMS grains) are a major component of cometary IDPs and so a major objective of this work is to elucidate their origins. In rare cases, GEMS grains have highly anomalous O isotopic compositions that establish their origins as circumstellar condensates [3]. Here we present data on a systematic study of the silicate components within a primitive IDP.

Methods and Samples. L2005AL5 is a fragment from a cluster particle (L2005 Cluster 13) and is comprised of crystalline silicates and sulfides, GEMS grains, and equilibrated aggregates embedded in a carbonaceous matrix. Nanometer-scale quantitative compositional maps of all grains in four microtome thin sections of L2005AL5 were obtained using a JEOL 2500SE 200 keV field-emission scanning-transmission electron microscope (STEM) equipped with a Noran thin window energy-dispersive X-ray (EDX) spectrometer. Spectrum images of the IDP grains were acquired by rastoring a 4 nm incident probe whose dwell time was minimized to avoid beam damage and element diffusion during mapping. Successive image layers of each grain were acquired and combined in order to achieve ~5% counting statistics for major elements. Following EDX mapping, the sections were subjected to O and N isotopic imaging with the JSC NanoSIMS 50L. Isotopic images were acquired in multidetection with electron multipliers. Images were obtained by rastering a ~1 pA, <100 nm Cs^+ beam over 10 - 20 μm fields of view. Each imaging run consisted of repeated (20 – 40) scans over the same area. Electrostatic charging was mitigated with the use of an electron flood gun. O and N isotopic images were acquired from 10μm grains of San Carlos olivine and 1-hydroxybenzotriazole hydrate (respectively) placed near each sample as isotopic standards. Images were corrected for EM deadtime, QSA, and instrumental mass fractionation with custom written software.

Results and Discussion. Coordinated high resolution chemical maps and O isotopic compositions were obtained on 38 GEMS grains, 11 single crystalline grains, and 15 equilibrated aggregates (Figures 1 & 2). Three GEMS grains and one equilibrated aggregate had anomalous O isotopic compositions and all of the remaining grains were indistinguishable (±50‰) from solar. The IDP had a bulk $\delta^{15}N$ of +160 ‰ with hotspots up to +800 ‰ hosted by organic globules [4]. ***Grain 1*** had a pronounced O isotopic anomaly ($\delta^{17}O$ = +523 ± 85 ‰; $\delta^{18}O$ = -100 ± 37 ‰), consistent with this GEMS grain originating from a red giant or AGB star. It is an elongated (0.3x0.5 μm) aggregate that is chemically heterogeneous on a 100 nm scale and subgrain element/Si ratios vary by factors of 2 to 3. The bulk composition is sub-solar as is typical for most GEMS grains (O/Si=3.6, Mg/Si=0.72, Fe/Si =0.48, S/Si=0.19, Al/Si=0.08, Ca/Si=0.04). The O abundance is stoichiometric, assuming that all Fe is present as metal or sulfide. The grain shows no evidence for zoning or element depletions at the grain rim relative to the core. No relict grains are observed. ***Grain 2*** is a 0.5 μm GEMS grain aggregate of at least 4 morphologically distinct subgrains based on the imaging and EDX data. It is moderately ^{18}O enriched ($\delta^{18}O$ = +80±20‰), but a sub-region reaches $\delta^{18}O$ = +145±30‰, possibly due to one of the subgrains. The subgrains are compositionally similar but differ in their abundance of metal and sulfide inclusions. The bulk composition is sub-solar except for Mg (O/Si=3.1, Mg/Si=1.20, Fe/Si = 0.43, S/Si=0.19, Al/Si=0.10, Ca/Si=0.06). No zoning profiles across the aggregate are observed and the O abundance is stoichiometric. ***Grain 3*** is an irregularly shaped GEMS grain only ~0.2 μm in size that is highly ^{17}O enriched ($\delta^{17}O$ = +1220 ± 260 ‰; $\delta^{18}O$ = -15 ± 55 ‰). The bulk composition is sub-solar except for Al/Si which is <2X solar (O/Si=2.7, Mg/Si=0.37, Fe/Si = 0.47, S/Si=0.26, Al/Si=0.14, Ca/Si=0.07). No zoning profiles across the GEMS grain are observed and the O abundance is stoichiometric. ***Grain 4*** is a ~0.6 μm elongate equilibrated aggregate consisting of a Fo90 olivine core decorated with smaller grains of diopside and pyrrhotite. The grain is ^{16}O-rich ($\delta^{17}O$ = -136±46‰, $\delta^{18}O$ = -140±45‰,).

The isotopically anomalous GEMS grains exhibit wide compositional variability and have morphologies that range from single objects to complex aggregates with numerous subgrains. The isotopically solar GEMS grains show a similar range in morphology, microstructure and chemical composition. Isotopically solar GEMS grains may have formed in the nebula under similar conditions to those that condensed in circumstellar outflows. Alternatively, they may have been isotopically homogenized by extensive irradiation/cycling of material in the ISM [5]. However, the average chemical compositions of most GEMS grains are inconsistent (non-solar) with this scenario [6]. Grain processing in the interstellar medium results in chemical and isotopic homogenization, yet the preserved microstructure of the presolar GEMS grains described here suggests that they were not extensively affected by irradiation, sputtering, or thermal processing and may represent relatively pristine circumstellar amorphous silicates.

Conclusions. GEMS grains in cometary IDPs have different origins and histories, and we recognize 3 subgroups based on the combined chemical and isotopic data: 1) A few % of GEMS grains are preserved circumstellar grains that condensed in the outflows of O-rich stars and survived exposure in the ISM and incorporation into their parent bodies, 2) some GEMS grains have homogeneous (solar) chemical and isotopic compositions and may be preserved ISM grains but these characteristics are also consistent with a local origin, and 3) most GEMS grains (~80%) formed in the early solar system as late stage non-equilibrium condensates.

References. [1] Messenger, S. *et al*. (2006) *MESS*, 187. [2] Molster, F. and Waters, L.B.F.M. (2003) *Astromineralogy*. Ed. T.K. Henning., Lecture Notes in Physics, vol. 609, 121-170. [3] Keller, L. P. and Messenger, S. (2007) *MAPS*, 42, 5297. [4] Messenger, S. *et al*., this volume. [5] Bradley J. P. (1999) *Science* 285, 1716 [6] Keller, L. P. *et al*. (2005) *LPS* 36, #2088.

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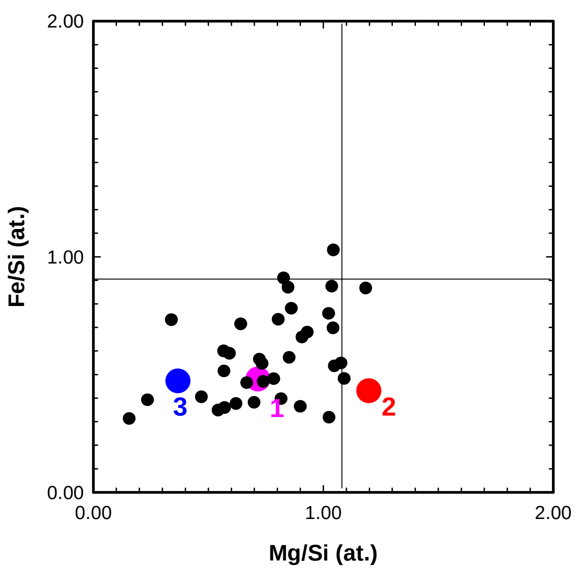

Figure 1. A plot of bulk Mg/Si and Fe/Si ratios for the analyzed GEMS grains in thin sections of L2005AL5. (the presolar GEMS grains are labeled 1, 2, and 3). The other data points are GEMS grains with solar O isotopic compositions. Vertical and horizontal lines are the solar values.

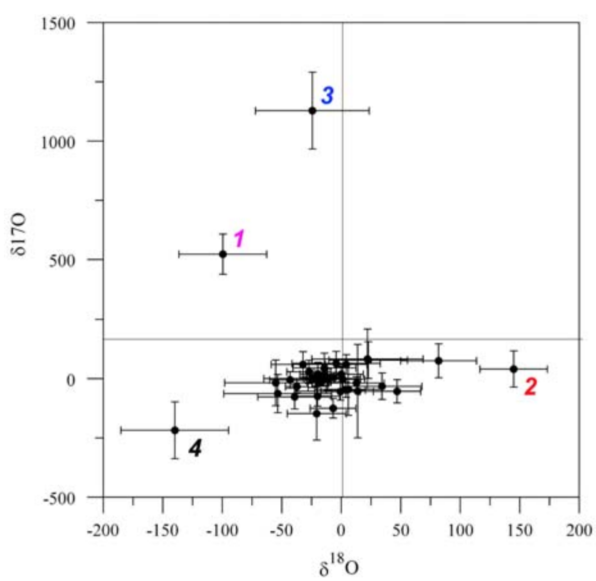

Figure 2. Oxygen isotopic compositions of GEMS grains in IDP L2005AL5. The three presolar GEMS grains are labeled 1, 2, and 3 (see text). Grain 4 is an equilibrated aggregate dominated by crystalline olivine (see above).